With the author's compliments

The Geological Formations of Manitoba

by R. C. WALLACE
Professor of Geology & Mineralogy
University of Manitoba

Published by
The Natural History Society
of Manitoba
1925

EXTRACT

Extract from the Constitution of the Natural History Society of Manitoba:

"The objects of the Society shall be: To foster an acquaintance with and a love for nature; to study especially the natural history of the Province of Manitoba; to encourage investigation and to publish the results of original research in all departments of natural history."

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ILLUSTRATIONS

PREFACE

This bulletin has been prepared at the request of the Natural History Society of Manitoba, and is published by that Society. Its purpose is to give a succinct summary of our knowledge of the geological formations of Manitoba, and thus to serve the needs not only of the student of Geology, but of the men and women of the province who may be interested in contributing to the advancement of the science by field observations in the district in which they live In the hands of the teacher, it may also serve a useful purpose in the schools, in stimulating an interest on the part of the pupil in the history of those earth forms with which he is familiar. The appended bibliography is reasonably complete, and will be useful to students who wish to deal with any phase of the subject in greater detail.

The author is indebted to Professor V. W Jackson and to the Department of Education for permission to use the map of Southwestern Manitoba (glacial), and to Mr Rudolph Hiebert of the Department of Geology of the University for the preparation of the fossil drawings and the sections of Manitoba, and for assembling the bibliography. He desires also to express his appreciation of the courtesy extended by the Director of the Geological Survey of Canada in permitting the use of Map 55A, which will be found in the pocket attached to the cover of the bulletin

Department of Geology,
University of Manitoba,
May, 1925.

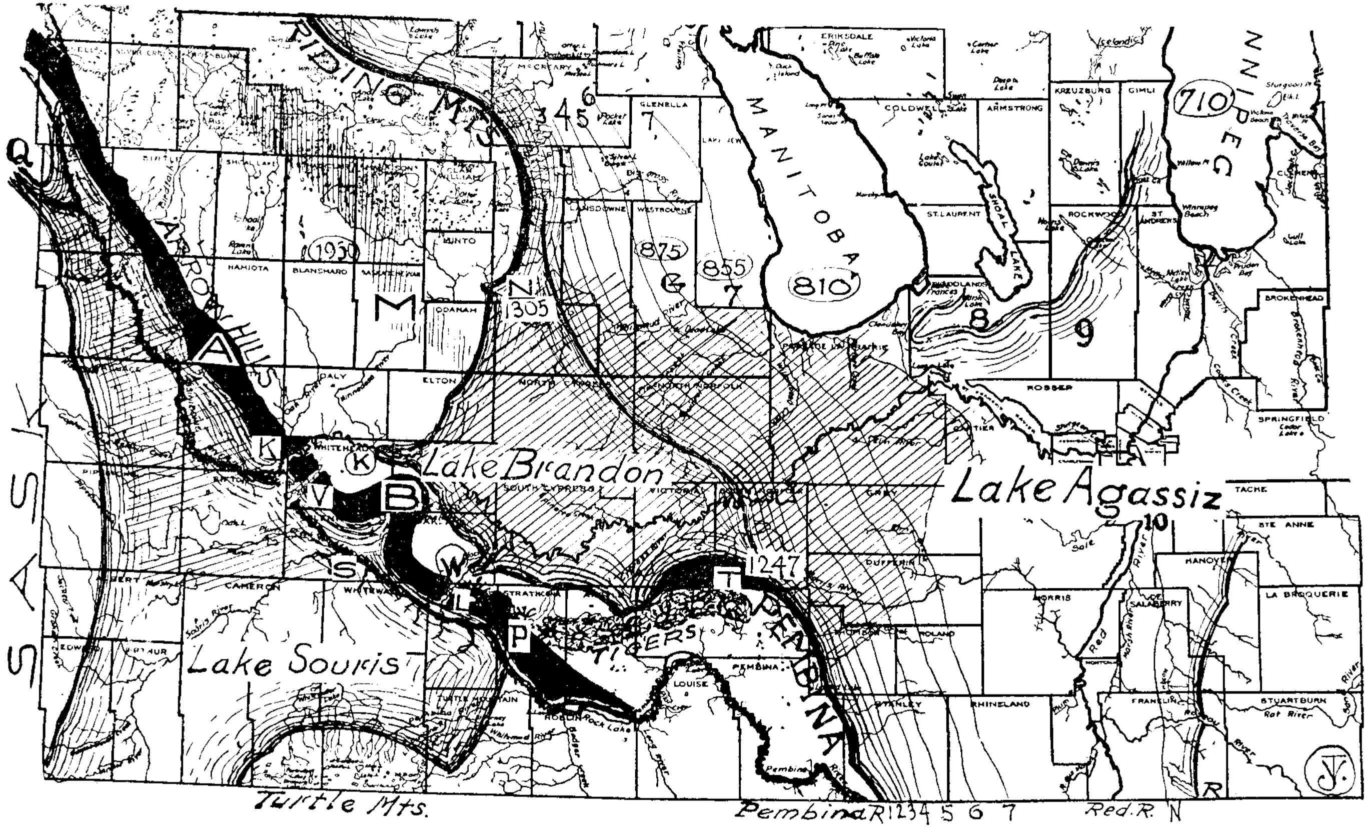

PLATE I—MAP OF GLACIAL GEOLOGY OF SOUTHERN MANITOBA

A K V B L P—Terminal moraine and northeast shore of Lake Souris. A—Arrow Hills. K—Kemnay break through. V—Big Slough or south flow of Lake Brandon. B—Brandon Hills. W—Wawanesa. L—Lang's Valley. P—Pelican Lape. T—Treherne corner of the Pembinas. P—T—Tiger Hills. G—S—P—The Early river along the terminal moraine (Qu'Appellt-Souris-Pembina). M—Minnedosa moraine. N—T—Neepawa-Treherne ridge (eastern limit of Lape Brandon. 1—7—Successive beaches. 1—The Upper Herman beach, 1,305 alt., three miles west of Neepawa. 3—The Arden ridge or Cambell beach, 1,084 alt. 6—The Gladstone beach, 975 alt., at G. 7—The Burnside beach, 855 alt. 8—The Argyle or Oswold ridge. 9—The Stonewall beach. Oblique shading—Delta sands.

THE GEOLOGICAL FORMATIONS OF MANITOBA.

I. Introduction.

Observations were made from time to time on the topography and geological formations of Manitoba by the early explorers, De la Verandrye (1734-1739), Pond (1778-1790), Thompson (1793-1805), Henry (1799-1808), Fidler (1794-1809), Harmon (1800-1819), Keating (1823), Franklin (1819-1827), Richardson (1819-1851), Palliser (1857), S. J. Dawson (1858), and Hind (1857-8). From 1873, more than half a century ago, with the work of G. M. Dawson, Bell and Spencer, and later Tyrrell, Dowling and Upham, there was initiated that systematic investigation by the Geological Survey of Canada, which has continued, under the later auspices of the Geological Survey and Mines Branches of the Department of Mines, to the present time. While very important observations were made by the early explorers they were necessarily isolated. Continuous work in the interpretation of the geology of the province may therefore be considered to be confined to the last fifty years, or somewhat more. It may be advisable by way of introduction to give a short statement of the result of that work.

There are many gaps in the geological column in Manitoba. The formations represented are the PreCambrian; Ordovician, Silurian and Devonian; the Cretaceous and early Eocene; the Pleistocene and Recent. Of these four groups the first is dominantly igneous, the second limestones and dolomites, the third shales, and the fourth clays, sands and lake deposits Cambrian deposits may possibly be concealed under the Ordovician limestones, but it seems clear at least that during the long time represented by the Carboniferous, Permian, Triassic and Jurassic in other areas, the Manitoba area was entirely above the sea: and that during the relatively shorter time represented by the Oligocene, Miocene and Pliocene no seas or lakes invaded Manitoba. The glacial (Pleistocene) deposits were in part due to ice movement and subglacia water flow, and in part to deposition in lakes hemmed in by the ice

as it finally retreated northwards; and the postglacial (Recent) deposits to river erosion, lake silting, and peaty growth since those glacial lakes have emptied out.

There are then four main time intervals in the geological history of Manitoba during which contributions have been made to the rocks now to be found in the province. The first is out of all proportion the longest in time value—the PreCambrian. It involves a complicated sequence of volcanic activity, sedimentation, mountain building and denudation on a vast scale—it may be not once but twice, with the final planing down of the high relief to a peneplain with but few elevations left. The rocks, both igneous and sedimentary, have been considerably metamorphosed by the intense pressure reactions during the period of mountain building. With the close of the PreCambrian there came to a close in Manitoba volcanic activity, and attendant mountain building (orogenic) processes. Since PreCambrian times there has been a continuous succession of periods of quiet sedimentation, and of elevation and erosion. The movement of elevation or sinking has been of the epeirogenic (continent-forming) type which has scarcely disturbed the horizontality of the sediments during the process of movement Accompanying those movements there has been no volcanic activity.

As the PreCambrian peneplain sank underneath the ocean, there was laid down a series of limestones which today flank the PreCambrian on its western margin, and at Hudson bay. This represents the second epoch in the history of deposition in the province The Palaeozoic seas, which may have covered the major part of the PreCambrian country now exposed, and which may have extended over what are now the western plains, were rich in invertebrate life; and the limestones, dolomites and associated shales of Ordovician, Silurian and Devonian age exposed in the region of the larger lakes of Manitoba are the repository of the richest and most varied fauna which the rocks of the province contain

The limestones were elevated and remained long exposed to erosive agencies. From the beginning of Carboniferous times to the end of the lower Cretaceous times there is no record of deposition in Manitoba. In upper Cretaceous times, however, not only western Manitoba, but the western plains as a whole, were covered by muddy oceans or inland lakes in which great thicknesses of shales and sandstone were laid down. It was not to be expected

that under such conditions life could flourish so abundantly as in the clearer seas of Palaeozoic times There are calcareous bands in the shales which are fairly rich in invertebrate remains; but on the whole the Cretaceous beds are relatively poor in traces of the life of that time. Deposition seems to have continued in Manitoba into Eocene times, as it did in southeastern Saskatchewan, practically without a break From late Eocene times onwards, traces of depositions are lacking, and the elevated shales were readily attacked by the erosive agencies which have had practically full play since that date

The last stage in deposition was the result of the southward progress of the ice sheets of Pleistocene times As a result of their erosive activity, there have been deposited on the surface of the older rocks boulders and eskers, moraines, drumlins and glacial till, while in the great glacial lake (lake Agassiz) which formed on the southward margin of the retreating icesheet bedded clays were deposited; and beaches were formed along the margin of the lake during the successive halts in the lowering of the lake surface. In Recent times rivers have cut their way through the glacial clays, lakes have to some extent been silted up, and extensive peat bogs have been formed on the surface of the glacial deposits. The topography of the country has on the whole been only slightly modified since glacial times.

In order to make more intelligible this short outline of geological changes in Manitoba which it was felt advisable to include in an introductory chapter before entering into a discussion of each period in detail, there is subjoined a table showing the main divisions of geological time, with the formations known to occur in Manitoba indicated in parallel table.

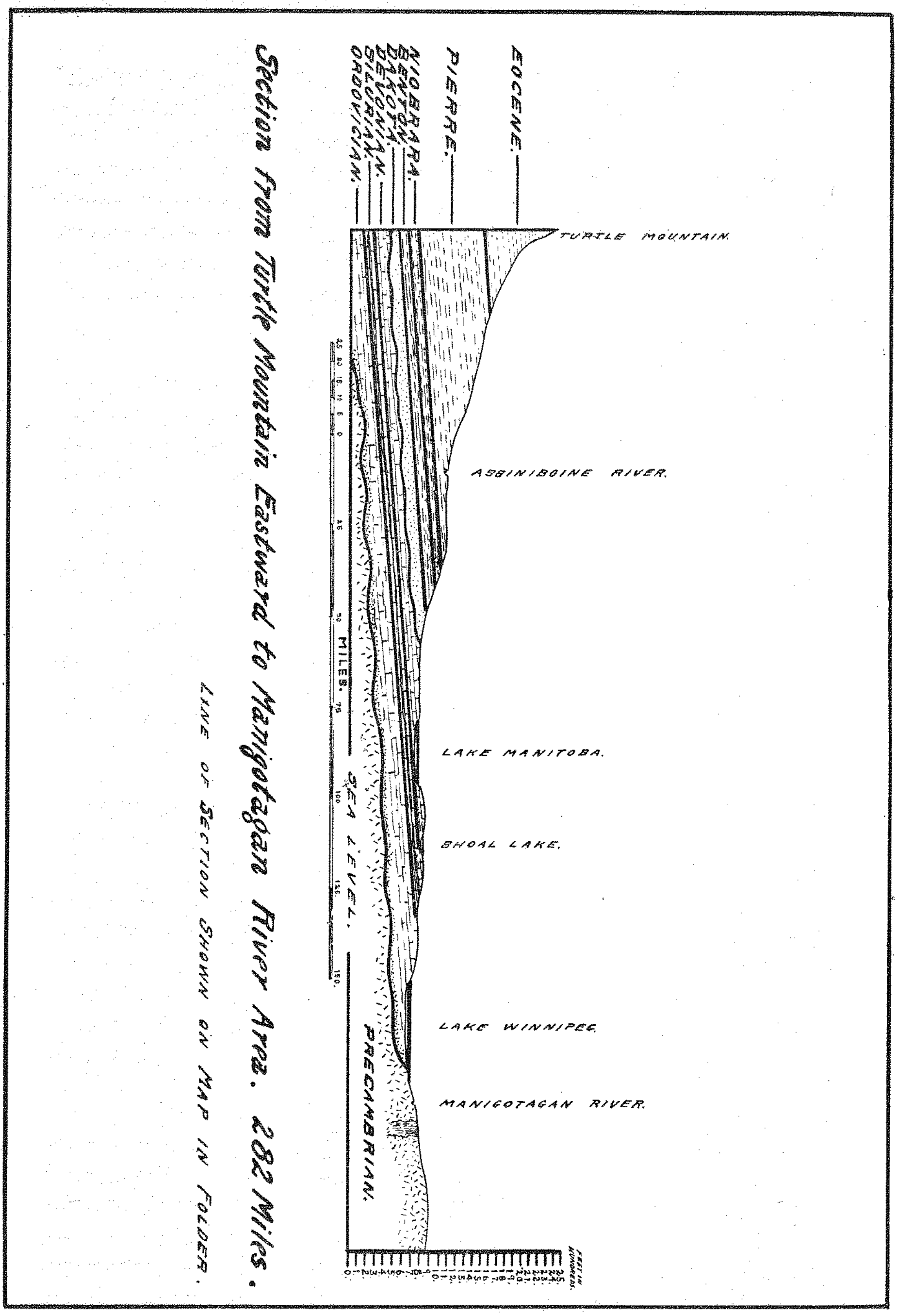

PLATE II

Geological Section of Southern Manitoba

	PERIOD.	EPOCH	EPOCH IN MANITOBA.
CENOZOIC ERA	QUARTERNARY	Recent Pleistocene	Recent Pleistocene
	TERTIARY	Pliocene Miocene Oligocene Eocene	Eocene
MESOZOIC ERA	CRETACEOUS	Upper Cretaceous Lower Cretaceous	Upper Cretaceous
	JURASSIC	Upper Jurassic Middle Jurassic Lower Jurassic	
	TRIASSIC		
PALAEOZOIC ERA	PERMIAN		
	CARBONIFEROUS	Pennsylvanian Mississippian	
	DEVONIAN	Upper Devonian Middle Devonian Lower Devonian	Upper Devonian Middle Devonian
	SILURIAN	Upper Silurian Middle Silurian Lower Silurian	Upper Silurian (?) Middle Silurian Lower Silurian
	ORDOVICIAN	Upper Ordovician Middle Ordovician Lower Ordovician	Upper Ordovician Middle Ordovician
	CAMBRIAN	Upper Cambrian Middle Cambrian Lower Cambrian	
PRE-CAMBRIAN		Keeweenawan Animikie Algoman Temiscamian Laurentian Keewatin	Algoman Temiscamian Laurentian (?) Keewatin

II. The PreCambrian.

Rocks of PreCambrian age are exposed in the eastern and northern parts of Manitoba. West of lake Winnipeg they are overlain by younger sediments; while immediately west of Hudson bay sediments of Palaeozoic age conceal the PreCambrian rocks. They are the surface formation in somewhat more than three-fifths of the total area of Manitoba; though the rock itself may be concealed to a large degree by soil, forest cover, or glacial clays. The western boundary extends from the southeastern corner of the province northwestward to lake Winnipeg, which is an erosion lake between the PreCambrian and the overlying limestone, northwestwards from the north end of lake Winnipeg to the Grass river, which with its lakes lies in or near the boundary up to its source, thence along the south side of Athapapuskow lake to the western boundary of Manitoba. The overlying Ordovician limestone stands out as a sharp scarp over a considerable part of this line, showing occasionally at its foot the PreCambrian floor. The Palaeozoic formations which, to the northeast, along the west side of Hudson bay, overlie the PreCambrian rocks, are exposed only rarely along the river channels, and are themselves covered by a great thickness of glacial drift. The boundary line is seldom seen, and is nowhere marked by a definite scarp as is the western boundary. It is drawn in a somewhat provisional way, pending more detailed work in that distant region.

The PreCambrian is the most complicated of the geological formations in Manitoba. It has been mapped in detail in only a few areas; and it has not been yet possible to correlate satisfactorily the results from the several fields. Much more work will be necessary before a reasonably complete picture can be obtained of the succession of events of major significance that took place in PreCambrian times, and over an immense period of time Much arduous work has been done; and for practically the whole of the mapping of this large and inaccessible part of the province officers of the Geological Survey have been responsible The intensive work which has been done in the mining areas in Ontario has been of assistance in throwing light on the problems of Canadian PreCambrian geology as a whole.

In the earlier work, it was believed that the granites and gneisses that form such an important part of the PreCambrian rock formations were the basement—the fundamental complex—on which all other PreCambrian rocks had been laid down The classical work of Lawson in the Lake of the Woods area in 1885 gave conclusive proof that there was an older rock than the granites and gneisses, a greenstone or altered lava, named by Lawson "Keewatin" into which the Laurentian granites had been intruded. The

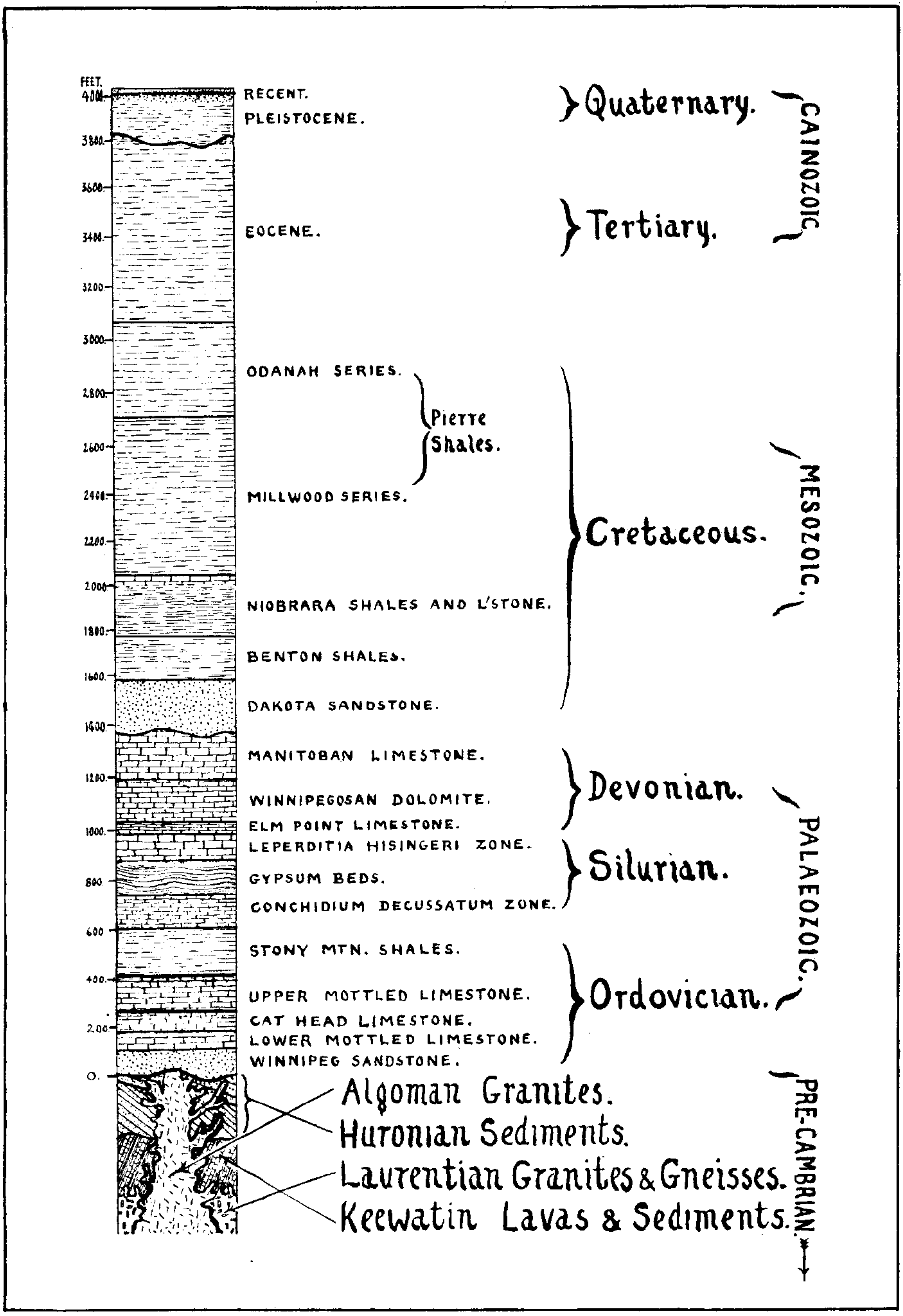

PLATE III

Column of Geological Formations in Manitoba

basement on which that ancient lava had been poured out has not been found—it has been swallowed up in the granite which later invaded and intruded basement and lava alike. Further detailed work in the Canadian PreCambrian showed that much of the granite which had been considered to be of Laurentian age was much younger, and that a second great period of plutonic activity and mountain building had taken place after the mountains of the Laurentian upheaval had been planed down by the agencies of denudation. This second period of orogenic activity was called by Lawson the "Algoman" revolution, and the granites of that age now exposed, the Algoman granites.

As work proceeds in PreCambrian areas, the exposed granites are being referred in greater measure to this later mountain-building period; and in all the areas which have been worked out in any measure of detail in Manitoba, the occurrence of granite of the earlier period is problematical, except such as may occur in the form of granite pebbles in conglomerates which were invaded by the later granite Associated with the later granites in geographical distribution, and apparently fairly closely associated in time, are gabbros, norites and lamprophyric dykes In the great mountain building movement a differentiation of the plutonic magma may have taken place, in part at least, into acid and basic phases.

The present day practice in PreCambrian work is to propose purely local classifications for each particular district, and to avoid the danger which lies in any attempt to correlate these classifications. It is therefore a somewhat doubtful expedient to submit a PreCambrian classification for the province. For the sake of clearness of discussion, however, the attempt is made, with the proviso that the formational names are submitted in a purely tentative way. The emphasis is on the time sequence of events, not on the correlation with formational terminology current elsewhere.

PreCambrian Formations in Manitoba.

E.	Granite intrusions Gabbro intrusions. Lamprophyric dykes.	Algoman (?)
D.	Arkose, conglomerates with large jasper pebbles.	
	Minor unconformity.	
C.	Quartzites, slates and greywackes. Conglomerates with pebbles, mainly of granite. aplite and felsite.	Temiscamian (?)
	Erosional unconformity.	
B.	Lit-par-lit intrusions of granite, now gneissose.	Laurentian (?)
A.	Basic and acid lavas with basal and interbedded sediments.	Keewatin and Coutchiching (?)

This table is drawn up to represent a complete succession of PreCambrian rocks in Manitoba territory, and is consequently much fuller than can be illustrated from any single district. There is considerable doubt as to the validity of the position of (B) in the table There are gneissose intrusions into the altered lavas (greenstones) older than the main granite intrusions (E), and which may be of age (B) The only indication of their being older than the conglomerate (C) is the presence of pebbles of similar gneiss in the conglomerate, and that evidence is not conclusive The facts will be better established when more systematic work has been done in the great granite areas of the PreCambrian. It has been suggested as well that rocks of Keweenawan age (the latest stage in PreCambrian times) may find a place in the Manitoba table. Amygdaloidal lavas with zeolitic infillings and traces of native copper occur in a small outlier of PreCambrian age in the Palaeozoic terrain near lake St Martin Lithologically they show considerable resemblance to the Keweenawan lavas of northern Michigan, but the limited exposure does not provide sufficient evidence to determine the age of the lavas and the associated tuffs. As there is some indication that the tuff beds were hardened by a granite which was probably of age (E), the Keweenawan member is not inserted in the above table.

The early reconnaissance work was done by Bell, Cochrane, Low, McInnis, Tyrrell and Dowling. As elsewhere in the Canadian PreCambrian the detailed work has been done in Manitoba in areas which are of economic significance on account of the mineral deposits which they contain. Detailed mapping has been carried out in two areas (1) the area north of The Pas, from the Manitoba-Saskatchewan boundary near Schist lake, eastward to Wekusko lake by Bruce and Alcock of the Geological Survey of Canada; and (2) the area east of lake Winnipeg from Wanipigow river southward to Lac du Bonnet by several workers, but most recently and in detail by Wright of the Geological Survey of Canada Other areas that have been examined in lesser detail are the Cross lake and Pipestone lake area, the Oxford lake and Knee lake area, the Nelson House and South Indian lake area, the Lower Churchill river area, the area between the Whitemouth river and the Winnipeg river south to Star lake and Falcon lake.

A tentative correlation of the work in the various fields has been given by Alcock and Bruce In general terms, the lavas of age (A), frequently ellipsoidal and always much altered, are associated with sediments which are usually younger, but in some cases (Knee-Oxford lake, Narrow lake) in part older, than the lavas. The older sediments may be tentatively correlated with the Coutchiching mica schists of Lawson in the Rainy lake area. In some areas the younger sediments are coarse, even conglomeratic, in others the fine sediments have been highly metamorphosed, with the development (Wekusko lake) of garnet, andalusite, staurolite and kyanite. The basic lavas are normally older than the acid lavas, and are characterised by the development of chlorite, while

sericite is the common product of metamorphism in the acid types.

Granites of age (B) are everywhere doubtful, and in some areas are definitely not to be found apart from the pebbles which occur in the conglomerates of age (C), and which may possibly be derived from a still earlier granite. Certain lit-par-lit intrusions of an acid sheared grey granite into the greenstones seem definitely older than the granites of age (E) and may represent the so-called Laurentian granite

The conglomerates of age (C) are the result of intense erosional activity, and have been highly sheared and intensely folded since deposition. The pebbles are of granite, gneiss, felsite, greenstone and, more commonly, quartz In some areas there are associated fine-grained sediments now infolded with the conglomerates. In only one area (Athapapuskow lake) has a second conglomerate been found (age (D)) separated by an unconformity from the earlier conglomerate just described. This younger conglomerate is characterized in places by the occurence of large jasper pebbles, and by a flatter attitude than that shown in the older conglomerate With the conglomerate is associated arkose, and the whole sedimentary phase represents disintegration and sorting of a local type.

The granites of age (E) are now, as a result of the denudation that has taken place since their intrusion, the dominant rock type throughout PreCambrian territory. They are normally fresh, massive biotite or hornblende granites, but there are associated as well older gneissose and more basic varieties, as well as younger pegmatites. There is evidence in all the areas that a complex of granite crops was intruded, probably over a long period of time, as a result of the vast mountain building movement which took place The basis plutonics and hypabyssal types are represented in the Cross lake area and elsewhere by diabase dykes, and in their most important occurrence in the Maskwa river and Oiseau lake areas by batholiths of gabbro. Many of the diabase dykes are later than the main granite intrusion, and may correspond in age to the Nipissing diabase of Ontario, of possibly Keweenawan age The gabbro batholiths of the Lac du Bonnet area on the other hand have been found by Cooke and by Wright to be earlier than the youngest granites of that area There are therefore basic types both earlier and later in age than the main granitic intrusions. To what extent they may represent differentiates from the acid magma must yet be determined.

The formations hitherto described, in all of which the granites of age (E) are intrusive, have suffered intense erosion subsequent to their intrusion by granites and elevation into mountain ranges. In the planing down of these mountains, the earlier formations have been worn away except in the deeper hollows where now lie the river valleys and lake expanses.

From the economic standpoint, the PreCambrian formations in Manitoba have received considerable attention, particularly in the areas above referred to, where detailed mapping has been carried

on. The granites of age (E) have been responsible for the introduction of gold in quartz veins and shear zones in the surrounding rock, particularly in the sheared lavas of age (B) Gold is found from Athapapuskow lake eastward to Wekusko lake; on Knee lake; from Hole river lake southwestwards to Bulldog lake, near the Ontario boundary, on Star lake and Falcon lake, west of the Lake of the Woods. From the same series of granites, sulphides of iron, copper, lead and zinc have invaded and metasomatically replaced mashed greenstones in shear zones and drag faults in Schist lake—Athapapuskow lake areas Sulphides of copper and nickel are associated with the granites and gabbros in the Maskwa river—Oiseau lake areas; and scheelite and molybdenite are associated with pegmatites which probably represent a late stage in the plutonic activity represented by (E) in the Star lake area. Banded haematite and magnetite occur in the sediments which are grouped under (A), but they have not yet been found to be of economic importance A reference to one of those occurrences on Knee lake, by Edwards in 1812, is the earliest statement with reference to metallic mineral deposits on record for the territory now included within the boundaries of Manitoba The mineral deposits in Pre-Cambrian territory have been dealt with in two provincial bulletins, one by Wallace, for Northern Manitoba, the other by DeLury, for Southeastern Manitoba

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III The Palaeozoic Era

(a) *The Ordovician Period.*

The PreCambrian surface on which the Palaeozoic sediments were laid down had been smoothed by erosion before Ordovician times to a peneplain somewhat of the type that it shows at the present time. The smoothness of the boundary line between Pre-Cambrian and Ordovician formations, as now mapped, would not have been possible had the PreCambrian surface on which the Ordovician sediments were laid down been one of high relief, and the uniform level of the PreCambrian floor at the base of the Ordovician limestones gives direct evidence on this point. That the final stage of peneplanation had not been reached is shown by an outcrop of PreCambrian rock near lake St Martin at a place where the PreCambrian surface, if reduced to a peneplain, should be covered by at least 600 feet of later sediments There was therefore a hill standing 600 feet above the level of the PreCambrian surface when the Palaeozoic seas invaded this territory. Such differences of relief are not found in the present day PreCambrian surface in Manitoba

The principal exposures of Ordovician age are the cliffs on the west side of lake Winnipeg From them, and from isolated exposures in the Red river valley, including Stony Mountain and East Selkirk, Dowling worked out a sequence for the Ordovician in Manitoba as follows:

Manitoba	Minnesota, Iowa, and Wisconsin
Stony Mountain Shales (190 ft.)	Maquoketa Shale.
Upper Mottled Limestone (130 ft.)	
Cat Head Limestone (70 ft)	Galena Dolomite
Lower Mottled Limestone (70 ft)	
Winnipeg Sandstone (100 ft)	Green Shales (Black river.)
	Plattsville Limestone.
	St. Peter's Sandstone.

The scarcity of fossils in the basal member, the Winnipeg sandstone, makes the correlation with Ordovician rocks to the south a matter of some difficulty The suggested correlation with Black river shales was made on the basis of some fossil material from the top shaly beds of the Winnipeg Sandstone. There is a possibility that the sandstone beds are to be correlated with the St. Peter's Sandstone, with which they are lithologically more nearly similar It has even been suggested that they may represent the Potsdam Sandstone of late Cambrian times, though not on the basis of any palaeontological data.

Winnipeg Sandstone.

The Winnipeg sandstone has few exposures in the Ordovician outcrop on lake Winnipeg and to the northwest As the rock is readily disintegrated, scarps are rare The sandstone varies in thickness from 100 feet to zero, the thickness depending to a great degree on the inequalities of the floor In many exposures, particularly towards the north, the sandstone is absent, and limestones of Lower Mottled age are seen to rest directly on the PreCambrian floor. The most important exposures of the Winnipeg sandstone are at Elk island, Grindstone point, Little Grindstone point, Black island and Punk island on lake Winnipeg, and on Simonhouse lake south of the Cranberry lakes on the Grassy river The formation is an unconsolidated or partially consolidated sand, occasionally deeply stained by iron but otherwise practically pure silica, frequently showing crossbedding, but nowhere a conglomerate base. The sandstone grades upwards into a more argillaceous phase, with clayey partings It is in this upper phase that a few fossils are found, which would apparently correlate that phase with Black river shales, the lower beds are unfossiliferous, and may be of considerably earlier age The species are Licrophycus ottawaensis, Serpulites dissolutus, Rhinidichtya mutabilis, Escharopora ramosa, Strophomena trilobata, Orthis testudinaria, Cyrtodontia canadensis, Aparchites tyrrellii, Conularia sp.

The conditions which made possible the deposition of sand in irregular basins in the early Palaeozoic seas, without conglomeratic phases, are difficult to interpret The sea in all probability advanced from the north and covered the area between Hudson bay and lake Winnipeg where now the PreCambrian rocks are exposed It would appear that the erosion of the peneplain by the

advancing sea was not extensive, else conglomerates would be seen, and limestones would not rest on the PreCambrian base, without intervening coarser sediment. There was probably a rapid advance of the sea over a surface which had been subjected to long continued subaerial erosion and conditions intervened which early gave rise to the deposition of calcareous ooze from the disintegration of the shells of the invertebrate animals which so abundantly populated those seas

Lower Mottled Limestone

The Lower Mottled limestone rests on the shaly upper beds of the Winnipeg sandstone The main exposures are at Grindstone point, Bull head, Dog head, Black Bear island, Tamarack island and Jack Head island on lake Winnipeg The argillaceous limestones which rest directly on the PreCambrian floor in Wekusko lake, Cranberry lake and Athapapuskow lake are probably of this age. Near its base the formation is argillaceous, but elsewhere a yellowish or buff-coloured limestone, characterized by darker brown spots which give the speckled or mottled appearance to the limestone The total thickness is estimated at 70 feet, and the richest horizon in fossils lies immediately above the argillaceous limestones at the base of the formation. The Lower Mottled limestones, like the succeeding members of the Ordovician system, are highly fossiliferous, and, like the Upper Mottled limestone, in particular, are characterized by the presence of very large types. Sixty-eight species have been identified from this formation, mainly cephalopods, gastropods and pelecypods The following are some of the most abundant: Receptaculites Oweni, Streptelasma robustum, Stromatopora canadensis, Orthis subquadrata, Endoceras subannulatum, Cyrtoceras laticurvatum, Asaphus susae, Ilaenus americanus

Cat Head Limestone

The Cat head limestone is exposed at Cat head, McBeth point, Inmost island, Outer Sturgeon island, Howell point and Robinson point on lake Winnipeg The rock of this formation, which is estimated to be 68 feet thick, is more dolomitic than is the Lower or Upper Mottled limestone, and does not show the mottling characteristic of the limestones which underlie and overlie it. The Cat Head limestone is recognized by the chert nodules, some of them of large size, which are found throughout the beds, but particularly at the base of the formation The cherts are distributed in horizontal bands, flattened along the bedding planes. They may represent the infillings into cavities left by the solution of large corals, on the other hand, they may have been formed by precipitation. Owing to the abundance of the nodules, the silica percentage of this horizon is unusually high for Palaeozoic limestone. The top beds are porous, honeycombed dolomites Forty-nine species of fossils have been determined from the Cat Head limestones The large cephalopods of the Lower Mottled limestones are not found, but the beds are unusually rich in fucoidal markings, four species of Chondrites having been determined. The following

are some of the fossils: Chondrites gracillimus, Chondrites cuneatus, Lingula elongata, Raphinesquina lata, Maclurea manitobensis, Asaphus gigas.

Upper Mottled Limestone.

The Upper Mottled limestone is exposed on the west shore of lake Winnipeg north of the mouth of the Saskatchewan river and on Selkirk island near Clark point, at Dancing point, near the mouth of the Dauphin river, at East Selkirk, Garson, Lower Fort Garry, St. Andrew's Locks, and east of Fisher Branch. The thickness is estimated at 130 feet. As the rock is exposed near Winnipeg, and as it is widely used as a building stone, the Upper Mottled limestone is much better known than the other formations of the Ordovician The rock is a very decidedly mottled light grey limestone, the darker rounded patches being either buff or blue in colour Wallace has shown that the darker areas are much more highly dolomitised, and are in all probability due to contemporaneous dolomitisation set up on disintegration of fucoidal material. Lithologically, the Upper Mottled limestone differs from the Lower Mottled limestone mainly in its chalky nodules, which can be picked out by the finger from the lighter coloured parts of the rock The quarries at Garson (Tyndall) and the abandoned quarries at East Selkirk give sections which are easily available for study. The quarry beds, together with a drill hole, give a section of 97 feet in the Upper Mottled rock, the lower 62 feet of which is so thin bedded as to be valueless as a dimension stone, and is much more argillaceous than the quarry beds. Seventy-five species of fossils have been determined from the Upper Mottled limestone, among them very large cephalopods, and compound corals also of exceptional size. It is difficult to select dimension stone which does not show some evidences of the extraordinary development in size of the faunal species of this time. Among the commonest are the following: Recepteculites oweni, Halysites catenularia, Columnaria alveolata, Streptalasma rusticum, Favosites prolificus, Raphinesquina lata, Maclurea manitobensis, Orthoceras Selkirkense, Ilaenus americanus.

Stony Mountain Shales.

The Stony Mountain shales and limestones, of an approximate thickness of 110 feet, are partly exposed at Stony Mountain and Little Stony Mountain, near the City of Winnipeg East of Fisher Branch, in deep ravines south of Fisher river, some of the red shale beds are seen At Stony Mountain the upper 41 feet of the formation is exposed, consisting from the top to the bottom of 14 feet of buff-coloured limestone (the quarry beds), 15 feet of yellow argillaceous limestone full of fossil casts, and 12 feet of red shales very rich in fossils Beneath that a speckled reddish limestone continues as determined by drilling for 60 feet, when a harder solid bedded limestone is reached which may represent the top beds of the Upper Mottled limestone. The top quarry beds are also exposed at Little Stony Mountain These quarry beds are not highly fossiliferous, but contain very large specimens of Beatricea nodulosa and Beatricea undulata; and on the floor of the quarry

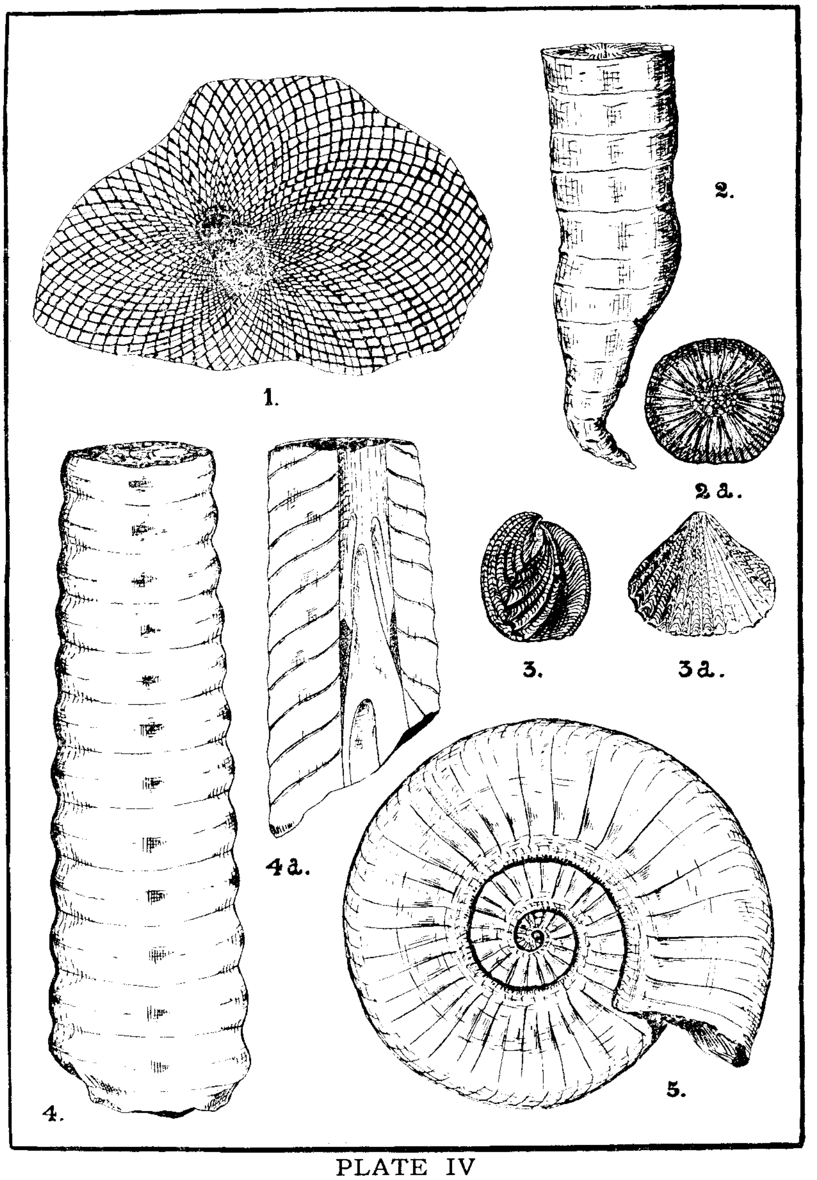

PLATE IV

Ordovician Fossils in Manitoba

1. Receptaculites oweni. (Hall). (Copied after Schuchert and Winchell).
2. Streptelasma rusticum. (Billings). (Copiel from drawing bf Lambe).
2a. S. Rusticum. Top view. (Copied from drawing by Lambe).
3. Rhynchetrema capax. (Conrod). (Side view). (Copied from Coleman and Park's General Geology.
3a. R. capax. Dorsal view. (Copied from Coleman aud Park's General Geology).
4. Endoceras annulatum. (Hall). (Copied from drawing by Hall).
4a. Endoceras annulatum. (Hall). Showing the inner structure. (Copied from drawing by Hall).
5. Maclurea manitobensis. (Whiteaves). View of specimen from convex side. (Copied from Whiteaves).

beds specimens of Favosites aspera are found. The yellow argillaceous beds hold many casts of brachipods; but the beds rich in fossils are the underlying red shales. Bryozoa, corals, brachipods and gastropods are the most numerous, and are very well preserved. Sixty-one species have been identified from the Stony Mountain formation, over 50 of them from the red shales. Among the commonest species are Streptelasma rusticum, Streptelasma trilobatum, Dinorthis subquadata, Rhynchotrema capax, Pleurotomaria bicincta, and numerous species of Bryozoa

Ordovician rocks are exposed in the Lake St Martin area, in the Grass river valley as a scarp on the PreCambrian surface, and on the lower reaches of the Nelson and Shammattawa rivers. They have not been subdivided as in the lake Winnipeg area Savage and Van Tuyl have made a detailed study of the fauna of the Nelson and Shammattawa river exposures On the Nelson river, the Nelson river limestone, with a thickness of 60 feet, is exposed at or above the Upper Limestone rapids It is a grey mottled limestone, with a fauna closely resembling that of the Upper Mottled limestone. It is overlaid (with an eastward dip) by the Shammattawa limestone (47 feet) at or immediately above the Lower Limestone rapids, which beds are also exposed for 15 miles on the Shammattawa river (38 feet), with a rich fauna closely resembling that of the Stony Mountain beds The similarity of fauna in the two areas is so marked as to indicate that there was continuous sea from Hudson bay to southern Manitoba, and probably to Wyoming and Colorado, from Trenton times to at least the close of the Ordovician period

From the economic standpoint, the important formation is the Upper Mottled limestone, which first at Lower Fort Garry, later at East Selkirk, and now at Garson (Tyndall) has supplied a building stone which has been used in many of the large public buildings in Winnipeg and other western cities The Legislative Buildings in Winnipeg are built of this stone, and the interior finish of the Parliament Buildings in Ottawa is of the same material The Lower Mottled limestone from Big island has been used for rubble, the quarry beds at Stony mountain are used for the same purpose. The pure sand of the Winnipeg sandstone at Black island and Elk island is well adapted for glass making, and may yet be used for that purpose.

(*b*). *The Silurian Period.*

Rocks of Silurian age are exposed between lake Winnipeg and lake Manitoba, along the Saskatchewan river from Grand Rapids westward to Cumberland lake, and on the Nelson river. The rocks are dolomites, with a gypsum horizon between the lower and upper dolomites. Deposition took place under shallow water conditions, and the fauna obtained from Silurian rocks in the southern area is much less varied and abundant than that from the Ordovician rocks. The best exposures are at the quarries at Stonewall, Gunton and Inwood, at Grand Rapids on the Saskatchewan river, at Cedar

lake and Moose lake, and on the northeast end of Lake Manitoba. Rocks of this age also show on the lower Nelson river.

Kindle worked out the following stratigraphical succession for the exposures from the Saskatchewan river southwards. The estimated thicknesses are by the writer.

Stonewall series—

Leperditia hisingeri zone, 100 feet.
Gypsum beds, 150 feet
Conchidium decussatum zone, 135 feet.

Conchidium Decussatum Zone.

The strata of the Conchidium decussatum zone (which Savage and Van Tuyl have shown should be renamed the Virgiana decussata zone), are found in the southern part of the province at Stonewall, Gunton, at Fisher Branch and at Grand Rapids on the Saskatchewan river. They have not been found resting directly on the Stony Mountain formation, but at Stonewall a cross-bedded sandstone succeeded by a red clay at the base of the quarries is probably the transition series from the Ordovician to the Silurian systems The quarry beds consist of a harsh dolomite, buff to grey in colour, pitted on account of the dissolving of fossils, mainly Favosites sp., but not rich in good fossil material. The Virgiana band is not found at Stonewall or Gunton (Tyrrell, however, records the occurence of Conchidium decussatum from Stonewall,) but is found northwest of Fisher Branch, and at Grand Rapids There is a thickness of at least 65 feet below the Virgiana decussata line in the Silurian of the Stonewall and Gunton exposures, and the total thickness of the zone from the base at Stonewall to the top of the Grand Rapids beds is approximately 135 feet. The part of the zone below the Virgiana decussata line is considered by Savage to be pre-Niagaran in age The following are some of the fossils from this zone· Aphyllostylus gracilis, Favosites gothlandicus, Favosites asper, Virgiana decussata, Spyroceras meridionale, Trochoceras insigne.

Gypsum Beds.

The gypsum beds are exposed and are quarried at Gypsumville, northwest of lake St. Martin. They are also found near the surface at Leifur, west of the south end of lake Manitoba, and have been found by drilling at Ashern, Rathwell, Arnaud, St. Elizabeth, St Charles and Dominion City. Their stratigraphical position, in the Gypsumville exposure, is placed on somewhat limited evidence, as they lie on or near the PreCambrian outlier, with little limestone associated with the beds, and are apparently very limited in distribution in that particular area. Their probable position is immediately above the Virgiana decussata zone and below the Leperditia hisingeri zone which is found south and west of the gypsum exposures By drilling, a total thickness of 150 feet of gypsum and anhydrite has been found at Gypsumville, of which the top 20 feet are quarry beds. There is a gradual change from gypsum to

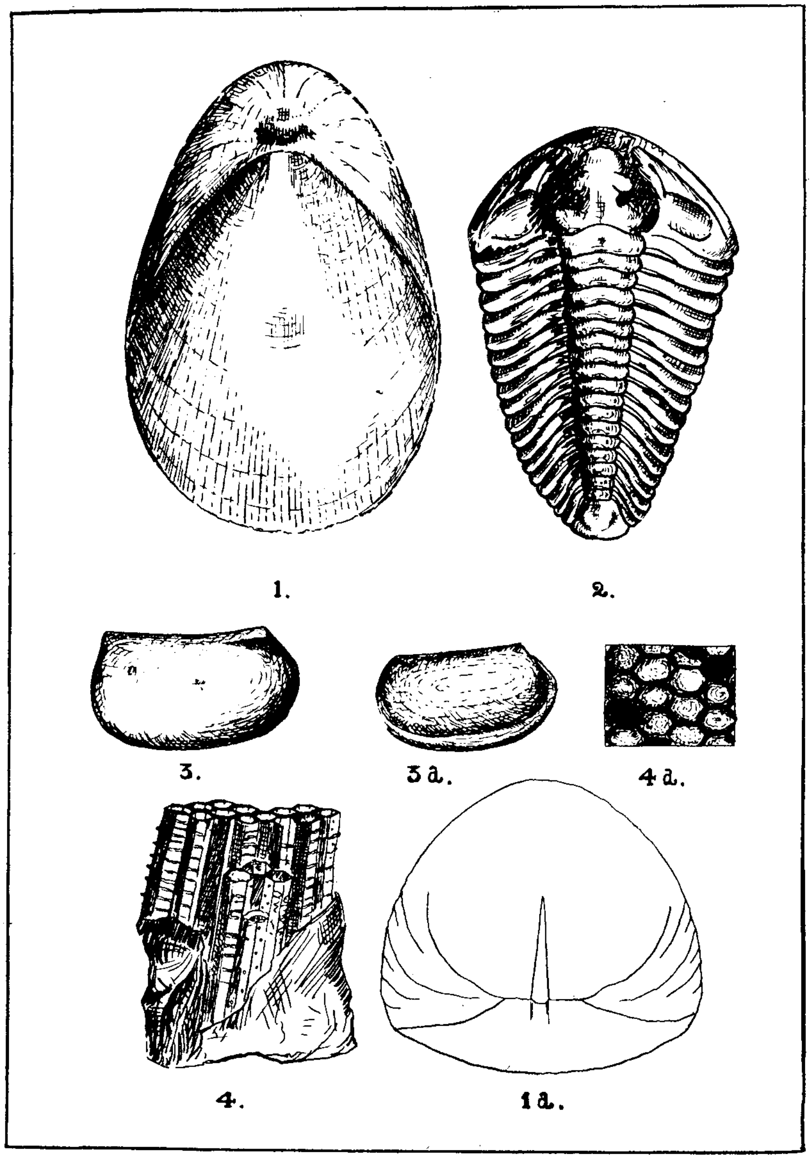

PLATE V

Silurian Fossils in Manitoba

1. Conchidium decussatum. (Whiteaves). (Virgiana decussata). Dorsal view. (Copied from drawing by L. M. Lambe).

1a. Conchldium decussatum. (Whiteaves). (Virgiana decussata). Outline of the posterior end of a cast of the interior of bot valves. (Copied from drawing by L. M. Lambe).

2. Calymene niagerensis. (Hall). (Copied from drawing by Hall).

3, 3a. Leperditia hisingeri. (Schmidt). (Copied from drawing in Von Zittel's Palaeontology).

4. Favosites asper. (D'Orbigny).

4a. Favosites asper. (D'Orbigny. View of colony from the top.

anhydrite with depth, and the gypsum has been derived, in part at least, from original anhydrite. The symmetrical folds which characterise the gypsum of the quarry beds appear to be caused by the expansion which accompanied the change of anhydrite into gypsum.

The conditions which gave rise to the deposition of anhydrite and gypsum in this area are not as yet fully elucidated. In the Gypsumville district it seems not improbable that the PreCambrian outlier had something to do with the isolating of a small deposition basin in the stage of shallowing of the Silurian seas; with the result that sulphates of lime were deposited in that district at the same time as dolomites may have been deposited elsewhere. Fuller drill records from Dominion City in particular would be of material assistance in establishing definitely the stratigraphical succession. In all the localities where gypsum has been found, it rests on red clays of considerable thickness At Dominion City a thickness of 60 feet of gypsum was reported, underlain by 110 feet of red clay and sand At Arnaud the gypsum is 25 feet thick, and the red clay 135 feet thick At Gypsumville the thickness of the basal red clays has not been ascertained by drilling.

Leperditia Hisingeri Zone

The Leperditia hisingeri zone consists of fine-grained dolomites, almost lithographic in fineness. They are exposed at Inwood, Broad Valley, on the Canadian National railway from Camper northwards to Old Gypsumville, on the east side of Waterhen lake, on lake Winnipegosis from Hill island northwards to Ami island, on Gross lake, Cedar lake and at Grand Rapids. On the lithographic dolomites rest deep red argillaceous dolomites on which the basal limestones of Devonian age in turn rest. In the Ashern district the Leperditia hisingeri zone does not exceed 100 feet in thickness. Tyrrell describes a section from Roche Rouge westwards on the Saskatchewan river which is probably considerably thicker. There is a striking resemblance between the lithographic dolomite of this zone and the Gower dolomite of the Niagara in Iowa in purity, fineness of grain, thin-bedding, cross-bedding, and association with chert. The rock is not very fossiliferous, but certain beds are crowded with ostracod shells, mainly Leperditia hisingeri. Other fossils are Favosites favosus, Glassia variabilis, Stropheodonta acanthoptera, Orthis flabellitis, and several stromatoporoids.

In the Hudson bay region, the Silurian rocks are exposed in Manitoba only on the Nelson river. The exposures are four miles below the Lower Limestone Rapids, and the 28 feet of yellowish dolomite there exposed have been named by Savage and Van Tuyl the Port Nelson limestone, representing, in the Hudson bay area, the Silurian beds up to, and including, the Virgiana decussata line. It corresponds approximately to the Stonewall, Gunton and Fisher Branch exposures in southern Manitoba From the fuller evidence on the Severn and Winisk rivers, it would appear that a continuous

sea extended from Hudson bay to southern Manitoba in early Silurian times.

The important beds from the economic standpoint are the gypsum beds. The lower dolomites of the Stonewall series are used for lime manufacture at Stonewall and Gunton, a very white slow-slaking lime is obtained The dolomite of the Broad Valley exposure (Leperditia hisingeri zone) which is of almost lithographic fineness, may yet find a market for interior decorative purposes. The gypsum beds at Gypsumville have been mined for over 20 years, and the industry supplies the needs of the prairie provinces. The raw material is shipped by railway car to Winnipeg, and there calcined and manufactured into building products. The raw material is used in the manufacture of Portland cement.

(c). *The Devonian Period.*

Rocks of Devonian age are found exposed on lake Manitoba are lake Winnipegosis, Waterhen lake, lake Dauphin, Swan lake, Red Deer lake, and in the immediately surrounding territory. They were classified by Tyrrell, who did the first detailed work on this system in Manitoba, as follows:

Manitoba limestone.
Winnipegosan dolomite
Red shales.

The Red shales placed by Tyrrell at the base of the Devonian, have been relegated to the base of the Winnipegosan dolomite The following classification has been given by Kindle:

Manitoban limestone, 185 feet.
Winnipegosan dolomite, 168 feet
Elm Point limestone, 25 feet.

Elm Point Limestone.

In the Elm Point limestone Kindle placed two exposures—that two miles north of Oak Point, and those on the shore of Lake Manitoba immediately north of Elm Point. The following localities may be added to those given by Kindle: Bannock hill, south of Ashern; quarry northeast of Moosehorn; island at north end of Waterhen lake; point Brabant and Graves point, lake Winnipegosis. The rock is a non-magnesian limestone, with argillaceous phases, and arenaceous in its upper beds The colour is light grey to dark brown, and shows in the Steep Rock quarry and elsewhere a very striking mottling with pebble-like masses of the dark brown rock in the light grey limestone. This is probably due to partial dolomitisation. Stylolitic flutings and pittings are very common. A very characteristic feature is the occurrence of thin beds packed with shells of Atrypa reticularis with peculiar marginal extensions (var. a of Kindle). In addition to this type fossil, the following are common in this formation: Atrypa spinosa, Productella spinulicosta, Paracyclas elliptica, var occidentalis, Euomphalus subtrigonalis, Loxonema antivolvis, Loxonema cingulata.

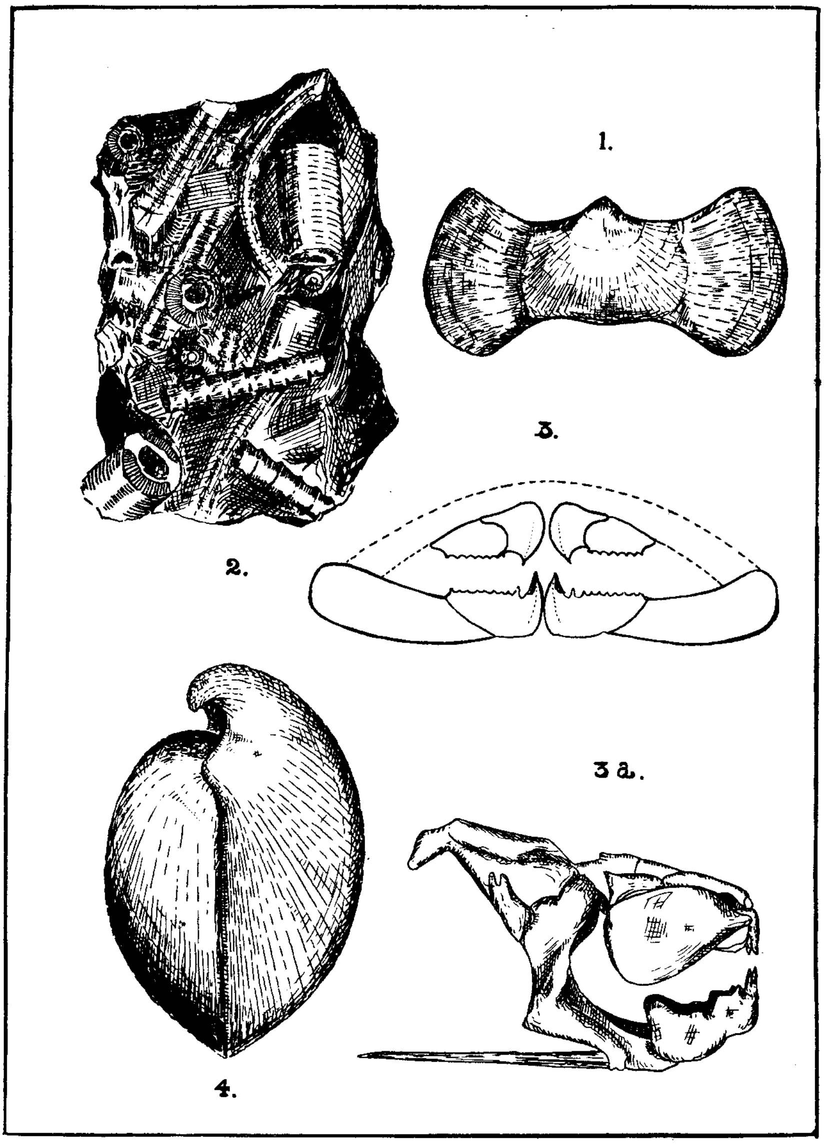

PLATE VI

Devonian Fossils in Manitoba

1. Atrypa reticularis. (Linnaeus). Var. A showing wing-like projections.
2. Crinoid stems in Winnipegosan Dolomite. Chiefly Ctenocrinus sp.
3. Dinichthys hertzeri. Jaws, copied from drawing by Newberyr.

3a. Dinichthys hertzeri. Skull. Drawing copied from figure in Graban and Schuchert's Geology. (This species has not been found in Manitoba but D. Canadensis has been reported).

4. Stringocephalus burtoni. (Defr.) Side view. After Von Zittel.

Winnipegosan Dolomite.

The Winnipegosan dolomite is best exposed on Whiteaves point in Dawson bay, lake Winnipegosis, and on the island northwest from that point. It is found also at Salt point, and the point west of Rowan island, Dawson bay, Hill island, Pemmican island and near Devil's point, lake Winnipegosis, and on the islands in Toutes Aides bay, lake Manitoba The rock is a harsh porous dolomite of light grey or cream colour, exceedingly hard and tough, full of fossils which are very difficult to break out from the rock. At its base is a red shale, seen by Tyrrell on Pemmican island, and found by the writer near Devil's point. A red argillaceous dolomite or shale also caps this zone, and marks the transition to the Manitoba limestone The characteristic fossil of the zone is Stringocephalus burtoni, which has a wide geographical range northwestwards through the Mackenzie basin, across to Asia and eastern Russia. Crinoid stems are very plentiful in this dolomite. The following are some of the commonest fossils: Cystodictia hamiltonensis, Atrypa reticularis, Atrypa spinosa, Stringocephalus burtoni, Productella spinulicosta, Glossites manitobensis, Proetus mundulus.

Manitoba Limestone.

The Manitoba limestone is exposed on lake Winnipegosis at Snake island and southwest of Charlie island, at the mouth of Mossy river, on the west side of Pelican bay, on the west side of Swan lake (south of Swan river), on Dawson bay between the mouth of Bell river and Salt point peninsula, on Red Deer river, and on the south shore of Red Deer lake. It is exposed also at several of the salt springs which are found near the west shore of lake Winnipegosis Lithologically, the rock is very similar to the Elm Point limestone, and the two horizons cannot be distinguished in the field on purely lithological grounds. The colour is greyish brown, the rock is very friable, and the fossils are extracted readily Heavy beds are seldom seen The mottling which was noticed in the Elm Point limestone in some localities is not in evidence in the Manitoban limestone; but stylolitic markings are very common in both formations At the base of the formation is found, in anticlinal folds east of Bell river, Dawson bay, an argillaceous limestone at least 21 feet thick. The top of the formation is seen on the south shore of Red Deer lake as an unfossiliferous sandstone with an exposed thickness of 1½ feet It is probably this sandstone which appears as inclusions in the brecciated beds at the top of the point Wilkins section

The commonest fossil in this, as in other horizons of the Devonian in Manitoba, is the brachiopod Atrypa reticularis, here without the peculiar flange shown in the Elm Point limestone beds. Kindle has divided the Manitoba limestone formation into two zones:

(b) Athyris fultonensis zone.
(a) Cyrtina hamiltonensis zone.

the upper zone including the upper 45 feet of the Point Wilkins beds, the Swan Lake limestone, and the rock exposed on Red Deer lake and Red Deer river above Pelican rapids. In lower horizons Athyris fultonensis, which is abundant in these beds, is not found; while Cyrtina hamiltonensis, found in the lower beds, is not found in the upper zone. The following are some of the characteristic fossils of the Manitoban limestone: Astraeospongia hamiltonensis, Alveolites vallorum, Atrypa reticularis, Atrypa aspera, Reticularia richardsoni, Cyrtina hamiltonensis, Paracyclas elliptica, Raphistoma tyrrellii, Dinichthys canadensis

The thicknesses of the Elm Point limestone and the Winnipegosis dolomite are given as estimated by Kindle. The estimated thickness of the Manitoban limestone as calculated by the writer, is based on the drill hole sections southeast of Charlie island, the Snake island beds and the Point Wilkins section.

A structural feature of interest in the Devonian exposures is the occurrence of numerous domes in all the Devonian horizons. In some cases there is a definite axis of folding, and the structural feature is a swollen anticline rather than a dome In most cases the elevation has taken place from a central point East of the mouth of the Bell river, the width of an exposed fold is 100 yards, and the height of the section at the central part of the fold is 26 feet. Such domes or folds are responsible for nearly all the exposures of Devonian rock on lake Manitoba or lake Winnipegosis. There is no evidence that they are coral reef or stromatoporoid reef domes; and an adequate explanation of this structural feature, peculiar to Devonian strata in Manitoba, is not yet forthcoming.

From the economic standpoint, the Elm Point and Manitoban limestone are, in certain beds, very pure non-magnesian limestones, and are available for Portland cement manufacture or for the pulp industry The quarry at Steep rock supplies limestone to the Canada Cement Company's mill at Winnipeg The Point Wilkins beds are of the same quality of limestone, but have not yet been used for cement purposes. Numerous salt springs issue from the Winnipegosis dolomite and the Manitoban limestones on the west side of lake Winnipegosis and lake Manitoba. They are a weak brine, and are probably formed from solution of salt crystals in the Winnipegosis dolomite by water circulating from the Dakota sandstone horizon For many years—from 1800 to 1875—the salt used at the Hudson's Bay Company posts and at the Red river settlement was obtained by evaporating these brines in iron troughs or kettles

Life of Palaeozoic Times.

In reviewing the life of Palaeozoic times, as indicated by the fossil evidence from the horizons of Manitoba, it will be noted that during the period of deposition from early Ordovician times to middle Silurian times the invertebrate fauna consisted in the earlier stages of large cephalopods, gastropods, cup corals and sponges, with abundant brachiopods, colonies of compound corals and

bryozoa. In the later stage of this period of deposition compound corals assumed greater relative importance, and the cephalopods diminished in numbers. Shallower water conditions intervened, gypsum was deposited in inland basins, and the period closed with shallow seas in which ostracods, brachiopods and stromatoporoids were the dominant forms of marine invertebrate life. The second period extends from early middle Devonian to late upper Devonian times. The marine life during this period consisted mainly of brachiopods, compound corals, crinoids, sponges and cephalopods, with brachiopods dominant. Spines of fishes are numerous in the upper beds, and this first order of vertebrates may have come in with the earliest Devonian seas in this area. The rocks are not well adapted for the preservation of fish fossils, and no good specimens have been obtained.

Of plant remains nothing but fucoidal traces—somewhat indefinite except in the Cat Head limestone, in which excellent specimens have been obtained—has been found in the Palaeozoic strata of Manitoba Of the abundant vegetation that flourished elsewhere during Carboniferous and Permian times, and of the amphibians which were the dominant vertebrates of those periods, no trace has been found in Manitoba. It would appear that the area under discussion was so extensively elevated after Devonian times that swamp conditions nowhere prevailed during the Carboniferous period. Such forests as may have flourished passed away without leaving any trace behind.

IV THE MESOZOIC ERA

Cretaceous Period.

The continental conditions which were initiated with the elevation at the close of Devonian times, were maintained throughout the remainder of the Palaeozoic era, and during the first two periods (Triassic and Jurassic) of the Mesozoic era as well. Not until upper Cretaceous times did the seas again invade the territory that is now Manitoba. There is therefore a gap of very long duration in the rock sequence, and the basal sandstones of Cretaceous age rest directly on the Upper Devonian limestones To represent the intervening time, nothing has been left in the territory under discussion.

The Cretaceous beds, which are exposed in the southwestern part of the province, and of which the hills of the Manitoba escarpment—Pembina hills. Tiger hills, Riding mountain, Duck mountain, Porcupine mountain and Pasquia hills—are built up, have been subdivided by Tyrrell as follows:

Pierre Shales	Odanah series,	400 feet
	Millwood series,	650 feet
Niobrara shales,		250 feet
Benton shales,		178 feet
Dakota sandstone,		200 feet

Dakota Sandstone.

The Dakota sandstone is exposed on the banks of the Red Deer, Armitt, Kamatch, Swan and Carrot rivers, and at Kettle hill on Swan lake. It was laid down on the eroded and irregular floor of the Devonian rocks (Manitoban limestone), and its thickness therefore varies to a very marked degree. The figure given above is probably the upper limit of thickness of this formation. It consists of white or reddish sand grading up into green sandstone and shale, the lower sands being in several exposures quite unconsolidated The sandstone may weather, as on Kettle hill, Swan lake, into rounded boulder-like masses It is not markedly fossiliferous, but contains impressions of coniferous leaves, fragments of wood, and the following fauna: Lingula subspatula, Ostrea congesta, Modiola tenuisculpata, and scales of fishes. This is an important water-bearing horizon, with considerable circulation, and not favourable for the preservation of fossils.

Benton Shale.

The Benton shale is very carbonaceous, dark grey in colour breaking down readily into thin flakes like graphite, and unctuous to the feel A section is exposed on Rolling river, a tributary of Swan river, on the north slope of Duck mountain, and again on Kamatch river, Porcupine mountain; and on Old Man river, Pasquia hills From a drill record on Vermilion river (Riding mountain) the thickness of the Benton formation was estimated to be 178 feet. The formation probably thins towards the north. These shales are poor in fossils. Fragments of Ostrea and Inoceramus have been recorded.

Niobrara Shales.

The Niobrara shales, unlike the Benton shales, are shown in many exposures in the Manitoba escarpment, more particularly in the river cuts on the north slopes of the Riding and Porcupine mountain, on Swan river and Assiniboine river. The beds consist of calcareous shale, with a solid ledge of limestone near the top of the formation, serving as a fairly definite horizon marker over the whole of the Manitoba escarpment. Owing to their hard nature, the beds are exposed in sharper cliffs than the underlying Benton shales, which are usually concealed. An interesting feature in connection with the Niobrara horizon is the abundance of Foraminifera in the rock, giving the grey shale a somewhat speckled aspect. The commonest species is Globigerina cretacea, but Globigerina bulloides, Globigerina limnaena, Textularia globulosa and several other species have been identified. The beds have a chalky aspect where the foraminifera are most numerous. In the limestone band the following are the commonest fossils: Ostrea congesta, Inoceramus problematicus, Belemnitella Manitobensis, Anomia obliqua. This band is found as far north as Old Man river on the west side of Pasquia hills and serves as an index bed in the Cretaceous exposures from south to north It represents the only limestone horizon in Manitoba later than Devonian times.

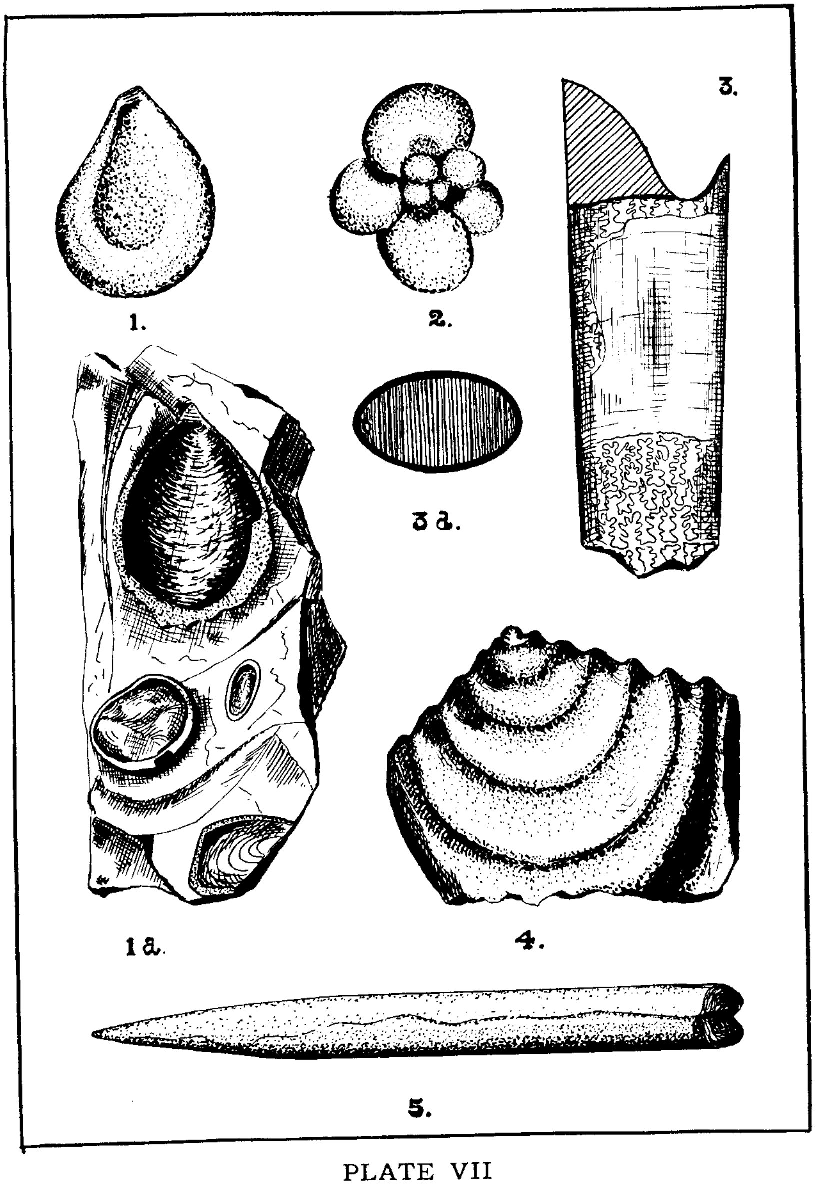

PLATE VII

Cretaceous Fossils in Manitoba

11. Ostrea congesta. (Conrad). Interior of upper valve. Copied from drawing by Stanton.
1a. Ostrea congesta. (Conrad). Group of attached lower valves. Copied from drawing by Stanton.
2. Globogerina bulloides. (D'Orbigny). Minn. Geol. Surv.
3. Baculites compressus. (Say). Side view, copied after Meek.
3a. Baculites compressus. (Say). Cross Section, copied from drawing after Meek.
4. Inoceramus sagensis, var. Nebrascensis. (Owen).
5. Belemnites sp.

Pierre Shales.

The Pierre shales form the uppermost beds in the Manitoba escarpment (with the exception of glacial clays) in Pembina hills, Tiger hills, Riding mountain, Duck mountain, Procupine mountain and Pasquia hills. They have been subdivided by Tyrrell into the Millwood(lower) and Odanah (upper) series. The Millwood shales are dark grey soft clay shales, exposed in the Assiniboine valley from Fort Pelly southward, at Minnedosa, on the Ochre and Vermilion rivers, on North Pine and Bell rivers They are not highly fossiliferous, but from an exposure on Bell river 16 species of Radiolaria were determined; also at Millwood a fauna of which the following is a partial list: Pteria linguiformia, Inoceramus tenuilineatus, Lucina occidentalis, Baculites compressus, Scaphites nodusus. These were obtained from ironstone nodules which occur plentifully in bands in the Millwood shales The Odanah shales are light grey in colour and break down into lenticular pebbles They are found in the valley of the Assiniboine river, on the Little Saskatchewan river at Odanah near Minnedosa, on Vermilion river, on Old Man river in Pasquia hills, and at La Riviere on Pembina hills. Hind found the following fossils from this series in an exposure on the Assiniboine river near the mouth of Two Creeks: Anomia flemingi, Inoceramus canadensis, Yoldia hindi, Lunatia obliquata, Cinulea concinna, Ammonites sp. Fossils are, however, rare in these shales.

The Cretaceous exposures in Southern Manitoba, from Pembina mountain westwards, have been worked out by Maclean. He has estimated the thickness of the Niobrara beds, as exposed, at 391 feet, and of the Millwood beds at 130 feet. A 3-8 foot bed of limestone is placed by him at the base of the exposed Niobrara section This seems to be the same bed as that placed by Tyrrell near the top of the horizon. It is exposed on the Assiniboine river, and is found by drilling at a depth of 28-55 feet below the surface at Morden. The upper 50 feet of the Millwood series consist of waxy clay, probably colloidal The Odanah series has a total thickness of at least 250 feet in this southern area; but the highest beds may have been eroded, as the glacial drift rests directly on the Odanah series In this area the main exposures of Odanah series are on Dead Horse creek, Pembina river, Assiniboine river and Souris river. From drill records they are apparently overlaid by colloidal clay in the southwest corner of the province

Indications of oil are found throughout the Manitoba escarpment in the Benton, and particularly in the Niobrara shales. The values are too low (8-10 gallons per ton) for successful distillation, and, though drilling has been done in several localities, no reservoirs of oil have been found. Small reservoirs of gas have been tapped in several places, and use has been made of the gas locally. An outcrop of marl in the Niobrara series at Babcock has been mined for several years for the manufacture of natural cement. Shale horizons in the Niobrara beds at Leary's west of Carman, and

in the Odanah series at La Riviere have been used for the manufacture of brick; and experiments have been made in mixing shale from the Niobrara and Odanah horizons for brick, hollow tile, and sewer piping, the purpose of the mixing being to reduce the high shrinkage on drying, and to modify the effect of the carbonaceous constituent of the Niobrara shales.

Life of Mesozoic Times.

In reviewing the life of Mesozoic times in Manitoba, the Cretaceous formations, which are all marine, give evidence of a somewhat limited distribution of lamellibranchs, cephalopods and fishes The muddy seas were not favourable to marine life. It is all the more interesting that there should be found in shales of Niobrara and Millwood age abundant Protozoa (Foraminifera and Radiolaria respectively) such as are usually held to inhabit fairly deep clear seas Of the reptilian life of Mesozoic times so abundant in the Cretaceous of Alberta, no trace has yet been found in the Mesozoic beds of Manitoba There are found in the Dakota sandstone pieces of wood and impressions of leaves, an evidence of coniferous forests in the near vicinity to the advancing sea in which the sandstones were being deposited.

V. The Cainozoic Era

a. Tertiary Period.

No detailed examination has yet been made of rocks of Tertiary age in Manitoba. They are known to occur in Turtle mountain in southwestern Manitoba, and they may possibly occur as well at the top of the Riding, Duck or Porcupine mountains; but rock exposures are concealed under a drift mantle In Turtle mountain there is a thickness of at least 800 feet of Tertiary strata above the sandstone which outcrops immediately south of Boissevain, and which is presumably of Fox Hill sandstone age, formerly placed with the Tertiary, now more frequently placed at the top of the Cretaceous. This sandstone is a friable, diagonally bedded rock, which hardens on exposure, and has been used as a building stone in Boissevain Above the sandstone are shales, clays and sands, with seams of coal which are found outcropping mainly on the northwest and northeast shoulders of the mountain These seams are found principally in the strata within 200 feet vertically above the top of the sandstone Their outcrop and probably extension have been mapped by Dowling The rock outcrops are very limited and little is known of the nature of the beds They are probably of freshwater deposition, as some freshwater shells have been found, and they are associated with coal beds not only at the base, but in a well-excavation near the top of the mountain as well. From what is known of the Estevan field in southeastern Saskatchewan, and of the strata exposed to the south in North Dakota, the upper beds in Turtle mountain probably belong to the Fort Union formation of Eocene age. No later Tertiary deposits have been found

During Oligocene, Miocene and Pliocene times it would seem that no deposition took place in Manitoba territory.

Dowling has estimated 160 million tons of coal in this area. It is a soft lignite, and has not yet been mined in quantity. For several years farmers in the vicinity of outcrops dug out coal from exposed seams for their own, or purely local, use. The seams vary in thickness up to 7 feet, but are usually much thinner, and are discontinuous in lateral extension. A borehole was put down by Dr. Selwyn at a point well up the mountain (Sect. 5, Tp. 2, Rg. 19) to 200 feet, but encountered no coal, and probably passed through a pocket of Pleistocene deposits.

b. Quarternary Period.

The Quaternary Period is divided into two subperiods (i) *Pleistocene* (Great Ice Age) and (ii) *Recent.*

(i) The Pleistocene is represented in Manitoba in all parts of the province. The icesheets which moved southwards over the province left deposits in the form of sheets of till, moraine ridges and drumlins, eskers and outwash gravel fans and erratics, while the lakes which were impounded in front of the ice formed beaches and delta deposits, and were responsible for the sedimentation of finely laminated clays and silts. The glacial deposits form a thin covering on the surface of the rock formations that would otherwise be exposed, and vary in depth from a few inches to over 200 feet, the latter very exceptionally. The hard rocks on which they rest have been smoothed and polished, and frequently striated, by the icesheet as it moved forward. The rock surfaces now exposed in PreCambrian areas in particular show the hummocky form, especially when viewed from the north, which is characteristic of glaciated country. The general movement of the ice was from the northeast southwestwards, though west of lake Winnipeg, in the southern part of the province, a southward or even southeastward movement of the ice may also be noted from the striations on the rock surfaces.

Johnston has described a till in the Whitemouth lake area which was probably deposited by the southeastward moving ice, and considers that this till has resulted from a later movement than the southwestward moving sheet, and may be due to deflection of the ice by the Manitoba escarpment. The numerous boulder islands (drumlins) on lake Winnipeg, together with some evidence of pre-glacial weathered surface on Deer island (vide Wright) might indicate that lake Winnipeg, in the later stage of the movement at least, lay in the line between the two sheets of ice. The gathering ground of the ice which passed over Manitoba lay mainly west of Hudson bay. Tyrrell has placed the centre of this—the Keewatin—ice sheet in the vicinity of latitude 62° After this sheet began to withdraw, according to Tyrrell, ice moved northwards, probably westwards and southwards from a gathering ground between Hudson bay and lake Superior—the Patrician centre. Still later the Labradorian icesheet came southwestwards; but to what extent the latter two icesheets affected the southern part of

Manitoba is not yet known. That the Labradorian icesheet moved southwest over the south end of Hudson bay is shown by the till containing marine shells which is exposed on the banks of the rivers flowing northeastward into Hudson bay. Tyrrell has found evidence on the lower reaches of the Hayes river which might be interpreted as indicating the western limit of the Labradorian icesheet in that area.

Two sheets of till have been recorded on the Hayes river and on the Shammattawa river; and two sheets are considered by Johnston probably to occur in southeastern Manitoba. Little evidence has been obtained of interglacial conditions from the beds which lie between the sheets of till No fossils have been found on the Hayes river. Tyrrell records moss and wood between the tills on the Shammattawa river. On the Rolling river, on the north side of Porcupine mountain, in sands underneath the till, considered to be interglacial, Tyrrell found the following:

Diatomaceae Navicula lata, Encyonema prostratum, Denticula lauta, Licmophora (?), Loccineis.

Phanerogama· Taxus baccata, seeds of a conifer, Elodea canadensis (?), Vallisneria (?).

Mollusca Limnaea catascopium (?), Valvata tricarinata, Amnicola porata (?), Planorbis bicarinatus, Planorbis parvus (?), Pisidiurn abditum, Sphaerium striatinum.

Moraines, outwash deposits and eskers were left by the retreating icesheet, and form topographical features of importance These have been mapped by Upham in the southern part of the province. The most important moraine is that which extends northwards from North Dakota into Manitoba through Rock lake, east of Pelican lake, thence northwestwards through the west end of the Tiger hills to the Brandon hills; and continuing again across the Assiniboine river as the Arrow hills northwestwards parallel to the river This (Itasca) moraine was the eastern rim of glacial lake Souris, which emptied at first southwards through the Sheyenne river, then through the Pembina river by way of Lang's valley, and later by the Souris river northwards to the Assiniboine river. As the ice receded another important moraine (the Mesabi moraine) was deposited on the eastern flank of the Pembina hills, northwards to the east end of the Tiger hills, is broken by the Assiniboine delta of lake Agassiz, and extends northwestwards through Basswood to the Riding mountains This represents the western margin of glacial lake Agassiz. East of the Red river, from South Junction northwards, through Sandilands, morainic deposits have been mapped by Johnston, and were apparently deposited in irregular fashion by icesheets advancing from the northeast and the northwest Many other morainic deposits are known in the province, but have not yet been systematically mapped.

Fluvioglacial sand and gravel deposits (eskers) formed by the subglacial rivers as they emerged from the icesheet, are illustrated by Birds' hill, northeast of Winnipeg, by Burns ridge, northwest

of Grosse Isle, and in isolated hills and irregular ridges. They show diagonal bedding, rapid change from sand to gravel, and other indications of a torrential river action They were probably gradually submerged under lake Agassiz as the ice underneath the sand and gravel disappeared.

The icesheet blocked the northward drainage, and glacial lakes—lake Saskatchewan, lake Souris and lake Agassiz—were formed Lake Saskatchewan (extending northwards from the elbow of the South Saskatchewan river) drained south into lake Souris through the Qu'Appelle valley, forming a delta which is now seen as the sand hills from Griswold northwestwards. The drainage of lake Souris has already been referred to Lake Agassiz, the greatest of the glacial lakes of the continent, had as its western boundary the Manitoba escarpment (Pasquia hills, Porcupine, Duck and Riding mountains, Tiger hills, Pembina hills). In Manitoba, North Dakota and Minnesota the extent of the lacustrine area of lake Agassiz was over 110,000 square miles. At the maximum development of the lake it occupied probably three quarters of this area, but was blocked by ice towards the north from ground which at lower stages was under the lake In successive stages the lake was drained, first southwards to Minnesota river and the Gulf of Mexico, and later northwards to Hudson bay The southward channel is well seen in the lake Traverse Big Stone lake valley The northward channel was probably at first by the Hayes river, the valley of which river bears evidence of much older and more extensive erosion than that shown in the Nelson river valley. The level of the lake was maintained sufficiently long at each stage to permit of the accumulation of beaches. which are very distinctly tracable, particularly on the western margin of the lake Twenty-seven of these beaches have been mapped by Upham, of which eighteen were formed when the lake emptied southward, and nine after the northern outlet had been opened. The highest is the Herman beach, at an elevation of 1205 feet at the International boundary, and 1305 feet at Neepawa. Owing to a differential elevation towards the north as the icesheet disappeared, the earlier beaches rise about one foot a mile as one proceeds northwards The depth of the site of Winnipeg at this earliest stage would have been over 500 feet below the surface of the lake Fourteen beaches are seen in the railway section from Thornhill to Morden East of the Riding mountain the beaches are again well shown, the Upper Campbell beach at Arden and northwards (Beautiful Plain) being particularly prominent The lowest beach on the west side of lake Winnipeg is approximately 85 feet above lake surface, but indications of still lower beaches have been found in the islands of the lake and on Traverse bay

In lake Agassiz, and in the smaller glacial lakes, sediment was deposited from the rivers which drained the icesheet and the land from which the ice had receded Where the Assiniboine river entered the lake a great delta was formed, extending eastwards from Brandon 75 miles to Portage la Prairie, northeastwards 50

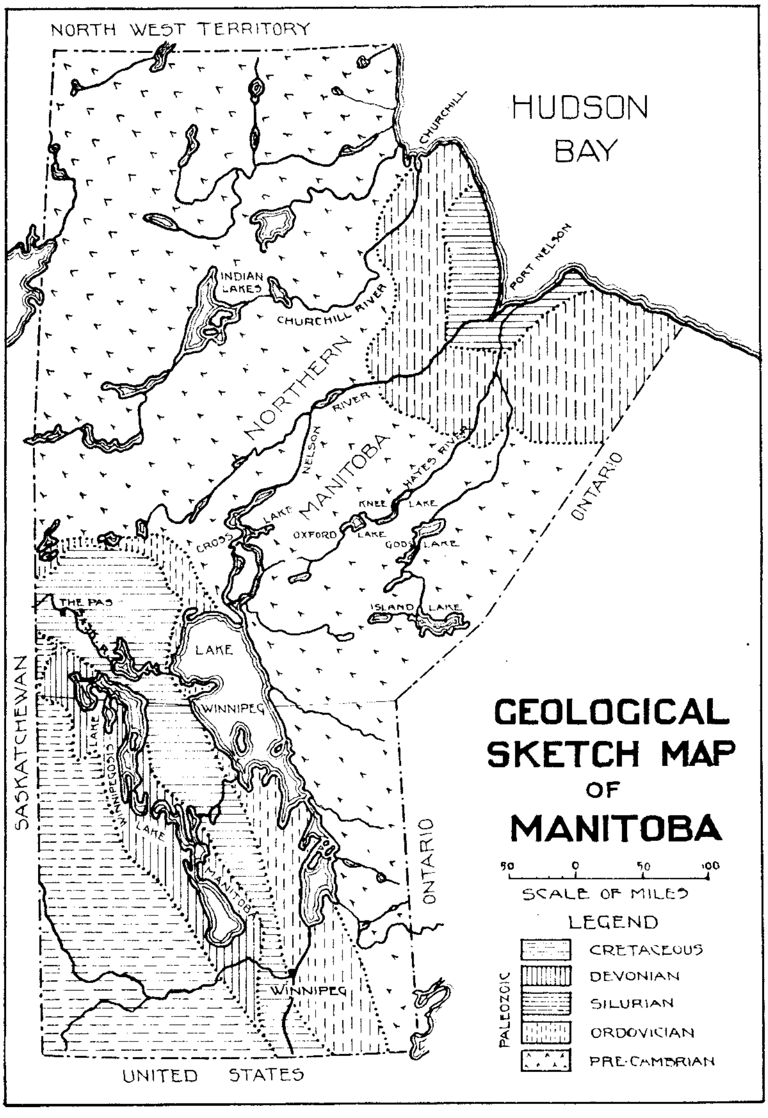

PLATE VIII

The Geological Formations of Manitoba.

miles to Gladstone, and east-southeastwards 80 miles into the Boyne river valley. The sand deposited in this delta has now been to a large extent reassorted as sand dunes. Where the Pembina river entered the lake a smaller delta was formed. The delta formed by the Assiniboine river at an earlier stage as it entered lake Souris (extending northwest from Griswold) has already been referred to. In the deeper parts of lake Agassiz fine silts and clays were deposited, and form finely stratified beds in the Red river valley. Near Winnipeg, the section of the upper 20 feet is as follows:

Soil—4 feet.
Sand beds—3 feet.
Clays (grey friable)—3 feet.
Yellow sandy bed—6 inches.
Clays (grey, finely laminated)—10 feet

The lower clays and upper clays are lacustrine clays The yellow band represents a time of shallowing, when the lake was almost completely drained. Johnston has suggested that temporarily an outlet may have been found through the ice, which was subsequently blocked. The sand beds were probably deposited by the overflow from the Red river or an earlier stream The total depth of the glacial deposit is 40-60 feet in the Winnipeg area, the lower half of which is mainly glacial till. Stratified lacustrine beds are not widely distributed over the basin of lake Agassiz. Such beds as were formed in the higher levels of the basin have probably been washed down to the valley and the rivers since glacial times.

Teeth of the mammoth have been found in the beaches of lake Agassiz Beneath the Herman beach, in North Dakota, there were found a mammoth tusk, three teeth, two vertebrae, and several other bones. In some of the beaches as well, chipped flints, evidently formed by man, have been found. Man came late in this area, but he worked and played on the shores of lake Agassiz as that lake gradually sank to its present dimensions.

(ii). Recent deposits are of small importance. They are delta deposits (at mouth of Red river) river sand or mud bars and levees, lake beaches, peat beds and swamp growths Since glacial times a drainage system is being evolved on the surface where the former channels were blocked by glacial deposits The new system is yet immature, and large areas are yet undrained, and in the form of swamps and muskegs are being filled up with plant growth which will ultimately be transformed into peat The rivers have as yet few tributaries, and relatively narrow valleys The topography has been little modified since glacial times.

From the economic standpoint the Pleistocene and Recent deposits that are of value are the sand and gravel of the beaches and eskers, used for road construction and building materials, and the clays of postglacial age which immediately underlie the soil covering. These clays have been used in St Boniface, Portage la Prairie and many other points in the province for the manufacture

of brick. Owing to the high percentage of lime in the clay, they burn as a rule to a pale grey or buff. The stratified clays of lake Agassiz are too stiff, and have too high shrinkage, to be of value for the manufacture of brick or other clay products.

VI. The Physiographic Features of Manitoba

The physiographic features of Manitoba are to a great degree dependent on the underlying geological structure. It is therefore possible, in a general way, to define physiographic areas as coterminous with the geological formations: (a) PreCambrian, (b) Palaeozoic, (c) Cretaceous and Tertiary. The features which have been determined mainly by the character and attitude of the underlying rock have been modified by the passage of the ice in Pleistocene times, which has smoothed down many of the sharpest details, and superimposed others of considerable physiographic importance.

(*a*) *The Physiography of the PreCambrian Surface.*

The PreCambrian territory, consisting of the harder granites or gneissose rocks, and the softer sheared lavas and sediments, was eroded to low level before Palaeozoic times. Since middle Palaeozoic times, it has been re-exposed almost continuously to denudation. The softer rocks, being less resistant, are the most deeply disintegrated With the passage of the ice sheet the weathered surface was swept away, the schists were plucked to a greater degree than the granite, and there was left a hummocky smooth topography with linear valleys in the bands of schists and sediments In these valleys the rivers now drain the PreCambrian surface, spilling from one cup-shaped depression to the next. Apart from the general drainage slope, the differences in relief are small, being not over 200 feet as a rule Any greater differences of relief are due mainly to glacial accumulation on the PreCambrian surface. As the general direction of the ice sheet was southwards, the rounded hummocky roches moutonnees aspect of the topography is more striking as one looks southward than northward.

Many of the lakes lie in the relatively easily eroded schists The outline of such lakes is determined very definitely by the attitude of the rocks, the long narrow bays being always parallel to the strike of the schist.

(*b*) *The Physiography of the Palaeozoic Surface.*

The flat-lying limestones of Ordovician, Silurian and Devonian age, exposed in the district of the great lakes in Manitoba, have been less affected by the icesheet, in the major physiographic features which they now display, than were the PreCambrian rocks. The sharp cliff features which often define the edge of the Palaeozoic limestone overlooking the PreCambrian surface, or lakes resting on that surface, were probably made more definite by ice-plucking, but are mainly of erosional origin. A similar origin obtains for the cliffs which are to be seen in the Devonian limestones and dolomites of lake Manitoba and lake Winnipegosis, cutting through the

dome-shaped elevations characteristic of that horizon. Elsewhere the shorelines of Palaeozoic rock are of a low shelving type, with few outcrops and frequent lagoons, bars and spits. The edge of the hard Silurian dolomite is marked by a definite cuesta in the Stonewall—Teulon area. The principal erosion features are the deep old river-valleys east of Fisher Branch, the Stony Mountain monadnock, and the pits and swallow-holes which indicate extensive underground solution in the area between lake Winnipeg and lake Manitoba. In general, the Palaeozoic surface is very flat, and very poorly drained

(c). *The Physiography of the Cretaceous and Tertiary Surface.*

The soft shales of Cretaceous and early Eocene age in Southwestern Manitoba have suffered intense erosion since they were elevated in Tertiary times. What is left in southwestern Manitoba, from the edge of the Manitoba escarpment westwards, is only a part of the original extent of the Cretaceous rock in southern Manitoba. The erosion along the eastern face of the shales has left a prominent escarpment extending from Pembina hills, through Tiger hills, Riding, Duck and Porcupine mountains, to Pasquia hills. This escarpment has been dissected by valleys formed by the Assiniboine river, Valley river, Swan river and Red Deer river, with other minor streams The escarpment now stands in isolated blocks, which form the hills above enumerated, rising from an elevation of 900 feet at the base of the escarpment of 2500 feet at the top. The smaller and relatively younger streams which dissect the shales have left exposed high cliffs of shale; and the Cretaceous surface is still in process of being actively denuded to lower level. The hard limestone bands in the Niobrara shales, and the ironstone concretion beds in the Millwood shales, are the most resistant and form the greatest number of outcrops. Elsewhere the soft shales are as a rule partly covered, even on the sides of deep river valleys.

(d). *Physiographic Features of Glacial and Recent Age.*

The main features of Glacial topography have been discussed in connection with Pleistocene geology, and in the preceding sections of this chapter. The moraines, eskers and beaches of glacial origin lie, generally speaking, in a north northwesterly trend. The drainage to the main northgoing channel is by tributary streams from the east and west. The drainage from the west in particular is to a great extent hampered by these glacial ridges. In this way there has formed, between the long ridge of relative dry land extending northwards, large swamps, frequently impassible. This is particularly noticeable in the country between lake Winnipeg and lake Winnipegosis north of the Little Saskatchewan river. Occasionally striking physiographic features result from glacial depositions, such as Brassey hill on the Hayes river, Brandon hills in part, the gravel and sand deposits west of Lac du Bonnet, and the sand dunes of the Assiniboine delta. The blocking of the drainage on the Pembina river at Lang's valley by glacial material

has resulted in the carving out of the Souris river valley below that point. The flat nature of the surface in the Red river valley, and in the Hayes and Nelson river areas, is due to deposition in glacial Lake Agassiz on the one hand, and in a larger Hudson Bay sea on the other The interrupted drainage caused by glacial deposition is since glacial times only gradually being restored, though not always along the original channels; and, as yet, the drainage is very immature

Apart from the river valleys of postglacial age, and the preglacial river valleys which have been reopened through the drift in Recent times, the most striking feature of post glacial topography is the high beaches which have been heaped up in our inland lakes These boulder beaches reach an elevation above lake level of 15 feet in Dawson bay (lake Winnipegosis), and an almost equal height above the lowlying ground behind the beaches. They are doubtless due to the presence of moving ice driven by the wind against the shore line when the lake ice breaks up at the end of each winter season

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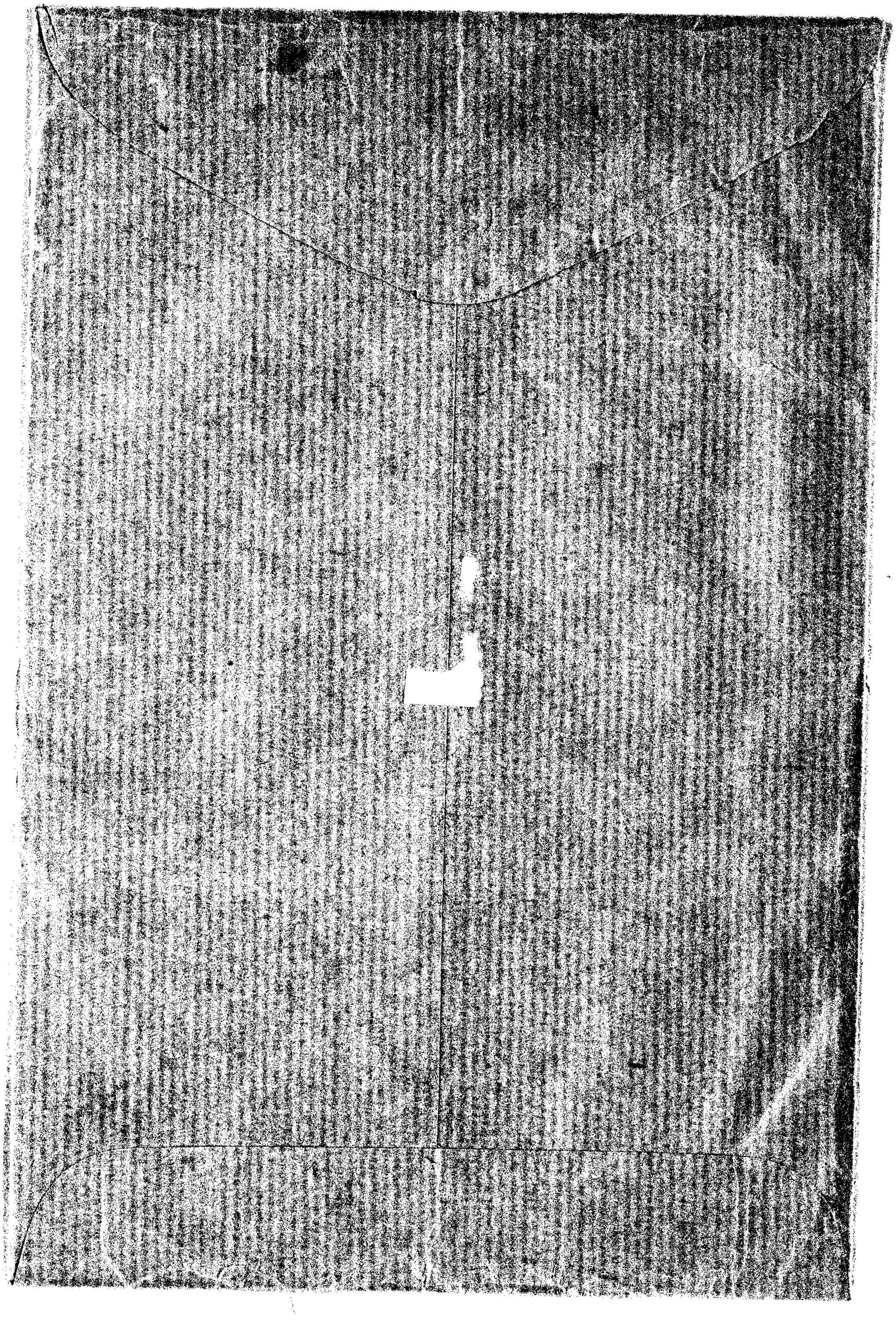
Hon. L. Coderre, Minister; A. P. Low, Deputy Minister
R. W. Brock, Director

MAP 55A

Geological Map of
ALBERTA, SASKATCHEWAN AND MANITOBA

35 MILES TO 1 INCH

To accompany Memoir No. 29



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